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FLAT CITY VERSUS VOLUMETRIC CITY, RE-APPLICATION OF THE LAYERED MOVEMENT NETWORK APPROACH

Abstract: *In cities of low or medium density it is possible to conduct a configurative analysis using mobility networks as main structural elements for the landscape (Bruyns, 2011, Read & Bruyns 2007). Expressed as a 'movement-function' indicator in three distinct scales, the overall results diverge from conventional typological driven analysis placing emphasis on movement patterns and how commercial functions cluster to each network. Not as a consequence of form but seen as an element that lends structure to the city, the 'Flat City' approach (Read, 2005) views mobility networks themselves as key structural indicator that highlight the social use of space, public as well as private. In contrast, high density cities, or aptly named 'Volumetric Cities' (Shelton, et. al., 2010), are challenged by spatial compression that establish other dependencies on mobility networks. Apart from the conventional use of movement networks, 'Volumetric Cities' place additional emphasis on pedestrian networks, interwoven with both the 'in' and 'exterior' conditions of the city. In this light, the question and applicability of the Flat City model remains questionable and as yet untested. This paper questions the applicability of the network driven model and its dependencies on movement networks in the context of the high-density landscapes. The paper will outline the basic premise of previous empirical work, before highlighting the challenges in the reapplication of this approach in the urban context of Hong Kong. As part of its aims, the discussion wishes to illustrate empirical work whilst possibly concluding on the adjustments deemed necessary for the re- application of this method in high-density urban landscapes in order to understand the formal expression of these cities.*

Keywords: *mobility network, layered, volumetric, urban morphology, morphology methods.*

Introduction

In cities of low or medium density it is possible to conduct a configurative analysis using mobility networks as main structural elements for the landscape (Bruyns, 2011; Read & Bruyns, 2006). Expressed as a 'movement-function' indicator of three distinct scales, the overall results diverge from conventional space-to-building typological driven analysis emphasizing the relationships between movement patterns and how commercial functions cluster to each network (Bruyns, op cit.). As a methodology the approach is only valid for economic data found at the level of the street.

The 'Flat City' approach (Read, 2005) views mobility networks themselves as key structural indicators. Not as a consequence of form but seen as an element that lends structure to the city, the model postulates the inherent emergence of a 'middlescale' network as third movement order that impacts both higher and lower hierarchies of connectivity which directly transform the use of space, public as well as private. This has led to two distinct conclusions. The first is the eradication of the central-peripheral model and its operative concepts of the 'more important' centre and its 'less important' peripheral relationships. Second, it has cast the foundations for a structural model whereby economic clustering is directly aligned with the configurative aspects of movement patterns and network distribution (Bruyns, 2011).

While ‘Flat City’ has gained grounds in showing scales of economic-spatial entities, morphological analysis remains limited when attempting to address overlapping, multi-level spatial surfaces or spatial density within vertical cities. The inclusion of floor area ratios (Maas, 1998) as well as other indices such as Floor Space Index (FSI), Ground Space Index (GSI), Open Space Ratio (OSR), Layers (L), Network density (N) as proposed by Spacemate (Berghauser Pont and Haupt’s; 2009a; 2010) have made strong gains in in terms of ‘density methodologies’, while building on the work of Angenot, (1954); Heijmas, (1965); and Rådberg, (1988) and their respective takes on dwelling density, land-use intensity, building coverage and spaciousness. Still these methods have remained limited in the inclusion of (a) spatial volumes and (b) commercial clustering and its pairing of economic indicators to spatial networks for multi-level building analysis.

In contrast, high density cities, or aptly named ‘Volumetric Cities’ (Shelton, et. al., 2010), are challenged by spatial compression that require additional dependencies other than mere mobility networks. ‘Volumetric Cities’ absorb pedestrian networks as part and parcel to both its ‘in’ and ‘exterior’ urban context, with commercial entities found in the covered internalised spaces, public or private. In this light, the applicability of the Flat City model to the volumetric domain remains, as yet, untested.

This paper re-applies the network driven model in the context of the high-density landscapes. First, the paper will outline the basic premise of previous empirical work of the Flat City model and its methodological parameters based on the historic centres of the Dutch Randstad. Thereafter, it will highlight the challenges in linking these spatial indices with volumetric conditions in multi-floor landscapes as a possible postulation of a volumetric driven urban methodology. As part of its aims, the discussion here wishes to align the volumetric concept and test the series of Flat City hypothesis in a series of step to mirror intentions with volumetric outcomes (Fig.1).

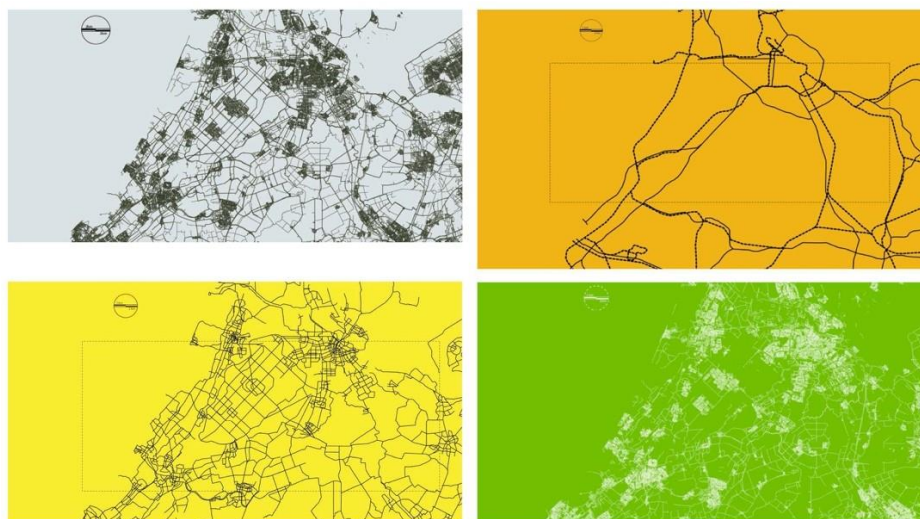


Figure 1. Movement network analysis, 3 orders of movement. Source: Bruyns, 2011

How the city functions. Flat city networks and economic clustering

Bruyns and Read’s research (2007) on Dutch cities, particularly in traditional city centres, have provided alternative spatial typologies for the classifications of the contemporary urban space. In this, the premise was one wherein the importance of movement and connectivity in cities constructed, as well as altered, spatial-economic entities based on speeds and intensity of movement. That’s to say, a movement centred hypothesis that questions ‘how the city functions’ and in what terms.

A first proposition of the working hypothesis was that urban form is legible through

orders of movement. Read's (1997; 2006) thesis delivered insight into the existence of a middlescale movement order, also termed the 'supergrid', linking scales of the city beyond the local and less than the metropolitan scales. As an addition, Bruyns's thesis (2011) has shown the possibility to express an urbanized landscape, in layers of hierarchies, focusing primarily on mobility networks and their attraction for economic entities to locate within each scale. At its core, both approached held to a hypothesis that mobility networks operate as devices or mechanisms through which to read urban structure as well as social dispositions, public and the private. In this deliberate move away from Space Syntax, and its mathematical dependencies on the topological conditions of line analysis, the revised methodologies are cognizant of networks structures of as 'sets' of distribution and intensities of use. In addition, the examination of movement infrastructures, road networks, or movement orders eradicated any pre-established spatial nomenclatures. Essential to its method, the separation of the networks allowed for the up-close examination of each network scale's formative characteristics in terms of distribution, grain of networks, network density, patterns and shape.

Three main movement orders (or layers) were proposed – one layer for each movement scale. One layer was dedicated for the metropolitan movement (orange), one for networks at the scale of the city region (yellow), with a final layer for the local or neighbourhood scale of movement (green). In each of the layers scrutiny fell on network structure (disjointed or continuous, clump like or single line networks) supplemented by photographic documentation to compare place structures, public use and ease of access. Thereafter a more detailed of each network was conducted, examining certain nodes specific to each scale. These included places of importance, places indicative of high intensities of movement and places where crossovers between scales of movement were obvious.

To address the question of '*how the city functions*' comparative data was deemed essential. This was to clarify the relationships between urban movement and the economic program of the city. A survey of all commercial activities at the street level classified each commercial entity through who uses it. Each commercial entity was represented by a single dot. Each dot was then coded in colour at scales of use. The method therefore required a corresponding 'layer' protocol similar to the layer analysis of the aforementioned networks. Four, and not three, economic scales were found. An orange layer was dedicated to the distribution of metropolitan commerce, with a yellow layer indicating middlescale commerce. The third layer, in green, showed local scale commerce. The fourth layer, in red, emerged because of it becoming clear that certain commercial entities were predominantly used by global visitors.

Similar to the network analysis, economic clustering, density of economic entities and economic patterns were then mapped, allowing comparison of economic data for established neighbourhoods, inner city global spots against clusters which remain almost hidden from sight (Bruyns, 2011). As concluding step, the research required an in-depth discussion on the spatial-economic comparison, termed 'place-region structures'. It was hoped that the configuration principles (relations and interdependencies) for public spaces, economic centralities as well as how spatial transformation occur would prove better insight when looking at the mechanics and details which formulate *place-regions economic entities*. This relational condition, between the networks and economic functions, produces a third indicator, which exposed the landscape as a context wherein a number of space-function scales have relational properties to each other. This confirmed the co-dependencies between spatial structures and economic clustering in terms of urban form and public space. For the historic centre of Amsterdam, it was seen that 4 spatial scales were present in one site. As such the nomenclatures for historic cores used by tourists were reframed as a *2 layer, 3 level open-ended structured global historic cluster* (Bruyns, 2011, p 260). Schiphol International Airport is characterized by the dominance of only 1 spatial scale, renaming its typological classification to; *a single layer, closed network-global centre*. In total 17 specific places where 'spatially' renamed (ibid).



Figure 2. 'How the city functions'. A survey of economic data for the corresponding area as in the network analysis. Source: Bruyns, 2011



Figure 3. Place-region economic entities. Relating movement networks to economic data, in three scales of use. Source: Bruyns, 2011

In conclusion, spatial formations and their ‘scalar commercial unit–network dependency’, has therefore replaced building–footprint indicators as grounding work for theorizing the morphology of the contemporary city and its movement distribution.

From the 2D to 3D, the ‘volumetric-economic city’ and the hypothesis of a Volumetric Methodology

The transference from the Flat City, to what we propose to term the ‘volumetric- economic’ model, is necessitated by the specificity of high density environments. First, in conventional medium to low density cities, a large variety of aspects can be easily represented in two dimensions. This method has proved very successful for both cartography as well as urban analysis (Conzen & Conzen, 2004). However, this approach remains problematic for dense, ‘vertical’ or ‘volumetric’ situations. What we view as the ‘ground’ or ‘urban surface’, in for example Hong Kong or Shanghai, remains a fractional part of the total FAR and building footprint. In these instances, the external, two-dimensional space is compressed, with a multitude of uses and functions appearing in the same three-dimensional spaces, only visible once the vertical dimension is added. In Hong Kong’s case, the ‘urban ground’ remains predominantly isolated dedicated for vehicular traffic, with most of the commercial activities operating on what is termed the ‘podium’ or elevated level above the ground surface (Sheldon, 2014). This is also true for subterranean pedestrian connections within the Metro and subways, or malls, acting as high intensity pedestrian conductors. Above ground and through buildings, the funnelling of commuters between transportation nodes on raised walkways or escalators means the connections between buildings and through buildings are of importance.

Secondly, these environments demonstrate tendencies that promote the fragmentation of both commercial and public spaces, compressing a higher density of functions into each available floor area. Thirdly, especially relevant for Hong Kong, the importance of land value and real estate values remains a key factor in determining as well as theorizing morphological typologies (cf. Higgins, Nel & Bruyns, 2018; Nel, Bruyns & Higgins, 2018 discussions on the questions of economic thinking and resilience in urban planning). Finally, research (See Bruyns; 2018, Bruyns, Landman and Nel, 2016) has begun to question the emphasis given to spatial isolation for domestic and public spaces within planning regimes. The matters of concern for us here is that how and in what manner the structural interpretation of the city will shift with the application of on methodology and how this application influences spatial, social as well as economic conditions of urban space.

What methodological aspects can be adapted from the Flat City model and, what adjustments would be deemed necessary to allow for the incorporation of both economic and volumetric data as part of a spatial and functional analysis of high density landscapes? The method and process described in what follows aligns our conceptualisation of the three-dimensional city and the first steps towards a general hypothesis and the application of the Flat City model in three dimensional terms. The method inverts the Flat City method and approach the city from the volumetric-economic as a starting point, after which it then incorporates the networks into the analysis. The method describes the first application as well as outlines some of the requirements deemed necessary to implement this as an independent method for configurative analysis.

From the outset certain existing tools seem inoperative for its application in a volumetric model. First, the application of Space Syntax within the volumetric context seems ineffective. This is due to its methodology not taking into account (a) topography

– unless the lines are weighted by travel time determined by topography. Nor does the method make allowances for; (b) incorporation of multi-modal transport, (c) integration of land use, (d) value or volume. Nor are any allowances made for (e) integration of a ‘z-value’ to height in its information and line structure. We are cognisant of the fact that Space Syntax only considers the spatial configuration of axial lines (2D lines), with newer versions of the model and program being able to include segments or street centre lines. More importantly, Space Syntax

relies on the visualisation of movement and its distribution without actual values (any values to be calculated are incorporated later within regression models). Four steps outline the testing of this hypothesis-methodology. Step 1 outlines the literal transformation to volumetric configuration, and spatial slicing of building volumes.

Step 2 introduces three-dimensional information to building structures. Step 3 examines the internalisation of the circulatory movement network within buildings both at the horizontal and vertical dimensions. Step 4 pits forward the possibilities of volumetric centralities.

Step 1: Flat City as the base (Fig 4). To begin to understand how these new complex spaces function, we seek ways to effectively *decompress* and expand *in* as well as *external* movement spaces. The first obvious step is to begin to incorporate a most basic element, being a third, vertical or volumetric, dimension to our concept of spatial morphology.

We propose to commence the volumetric approach harnessing GIS software, and its inherent allowances for three-dimensional modeling (i.e. ArcGIS 10 and up). For the purposes of the discussion here we have used a simplified version of the context to illustrate each step¹.

In order to address our general premise, our proposed method questions the possible addition of a third dimension in how we move through cities and buildings.

The traditional two-dimensional movement network remains a key component and basis for this analysis. This part of the movement network should be prepared in a similar way for any conventional movement network analysis, that is to say, one map that includes all the lines of mobility under scrutiny. The other base component is building footprints, attributed with (i) overall building height and (ii) floor heights or number of floors. These form the basis on which to construct the various three-dimensional structures that directly link to the city's ground.

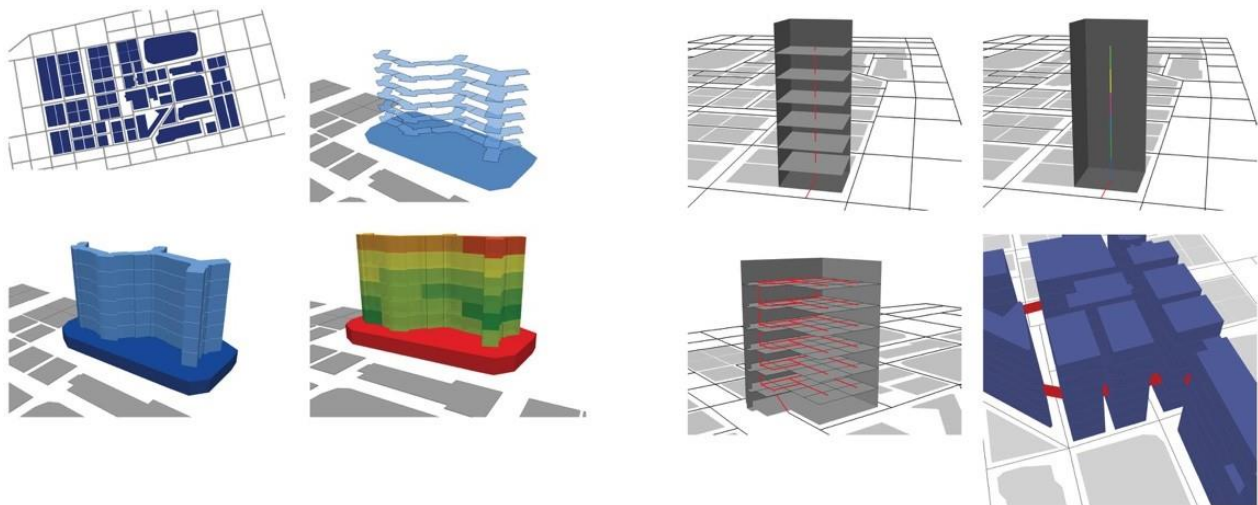


Figure 4. Volumetric transformation. Two-dimensional city transforming into volumetric data sets. Source: Authors, 2018

Step 2: Sliced approach - adding 3D information to buildings (Fig 4). When faced with a lack of attribute data, the second step introduces the *sliced* approach to building volumes. Although there is already a vast array of 3D modelling software and formats (AutoCAD, Rhino or Sketchup), many of the models, when imported into GIS software, do not retain any of their attribute information (i.e. floor, use, value).

¹ A range of technical requirements are deemed necessary for this method to be used in various software's. First the basic requirements of using **Polygons** for all units and spaces of measure; i.e. building, parcel space, area per use/function (can include per floor), floor heights. For **the Networks, the requirements:** can include multi-modal networks lines for car, rail and pedestrian scales.

Herein, each floor of the building is represented as a 'slice' in the overall volume. Each slice is created by drawing the surface areas per floor. This can easily be done by tracing the footprint of the building multiple times on top of each other, effectively adding multiple layer of the building. Each of these slices can also be partitioned to represent rooms, offices or zones within buildings. Care should be taken in buildings which have a podium structure. In turn these spaces produce urban and spatial amenities in places where spatial availability is at a prime. Each podium can then accommodate a number of high rises, feeding directly into each podium. Within the analysis, the podium should only be used for the appropriate number of floors and should not represent the entire building.¹

Though the process of generating the slices for each building, attribute data (bottom elevation (i.e. floor elevation) and the top or roof elevation for each floor) would be required to supplement the spatial configurations of structures. For example, if the building is five stories in height and each floor is 3 meters high, the first floors bottom elevation will be 0 and the top elevation will be 3. The second floors bottom elevation will be 3 and top elevation will be 6. This process would then be repeated until the entire volume is represented.

Using the ArcGIS '*Feature To 3D By Attribute*' tool, each of the slices can be give an elevation value (or z-value) which is directly encoded into the slice, allowing the slice to automatically appear at the correct elevation when seen in three-dimensions.

With the completion of the various 'slices' and relevant attribute data added, the extrapolation to volumetric properties can be made. Of importance here is the inclusion of functional use of the spaces, indicated per colour. In the model we used red to indicate commercial, residential in yellow and office spaces in blue. Other options, for example, the land value per cubic meter are another possibility (cf. discussion on values of spaces in Higgins, Nel & Bruyns, 2018).

Step 3: Internal network (Fig 4). Similar to the Flat City model, step 3 compares economic functions with the network analysis. More specifically this step relies on the addition of the internal network to building volumes. For this step the two-dimensional network forms the base for which the three-dimensional network will be extended.²

The first part of this process is to identify where the building connects to the external larger movement network, as one or a series of lines. Thereafter consideration is given to the presentation of the internal network which is dependent on the needs and resolution of detail. In this, two options are possible. The first is the use of only a single path-line that moves vertically through the building to represent and elevator, stair or escalator for example. The sections along the path-line can also be divided up and given different attributes. In this, each section can be given a time value to represent the mean time it takes to move in that section or time for the elevator. An alternative option is to use a detailed internal network for each building, showing connections to each room, office or zone as well as vertical distribution elements as stairs or elevators. More accurate results will be provided in the latter form of analysis but would require high resolutions of detail and a finer grain of internal division within each building.

At the network level additional detail is also possible. Each network could reflect all publicly accessible paths (both public and private paths-lines that the public has access to) within each network structure. In cities as Hong Kong and Shanghai, the value of this approach could enrich spatial analysis as many buildings in these cities are dependent on the raised connected walkway systems that are public as well as private, local as well as metropolitan in scale of connectivity. In addition, the importance of enhancing network data exposes a gap in the morphological debate

¹ This is specifically applicable to the Hong Kong urban landscape and its developmental typology of the podium structure as main public and circulatory spaces with additional commercial or residential spaces situated above the podium in a number of levels.

² Important to note that the type of line must be able to handle z-values in the GIS. Additionally, the same approach to the network creation should be taken to make the network routable as with any other network.

with the predominant inversions of public spaces in Asia, altering both the modes of urban connectivity in high density situations as well as forms of economic centralities.

Historically a buildings location to the street level network was deemed sufficient spatial exposure whereas the current pressures placed on economic performance become exponential with the increase in density and the sheer verticality of cities like Hong Kong. A collection of buildings in Hong Kong, for example Tsing Yi, equals both the population and volumetric densities to that of a small village in Europe. The interconnectivity of the spaces through and in-between buildings (above, on and subterranean) continuously call for new approaches to investigate both spatial understandings as well as the values through which they are measured.

Step 4: Volumetric centrality. Step 4, the final step, calculates the inverted network centralities of the individual spaces per floor for a series of buildings. Reach, Gravity, Betweenness, Closeness and Straightness of movement networks remains one easily calculative step as basic centrality metric (cf. Sevtsuk and Mekonnen (2012) and Kang (2017)) (See Table 1 for calculation formulae). In summary, the *Reach index* is an accessibility index and is defined as the total number of locations that can be accessed within a specified radius of a network or topological structure. The reach index can also be weighted (i.e. with population, value or volume) so that the index calculates the sum of weights with the specified radius for all locations. A higher value for the reach index indicates that more locations or weighted values are accessible within a given network distance (Kang, 2017; Sevtsuk, 2014; Sevtsuk and Mekonnen, 2012). The *Gravity index*, the second measure, builds on the reach index by adding a spatial impedance factor to measure how many locations are accessible within a given distance. This measure considers accessibility to a location is proportional to the weight (attractiveness) of the destinations surrounding the location and is inversely proportional to the network distance between the location and the destination (Sevtsuk, 2014). More importantly, the gravity index shows the attractiveness of a destination whilst indicating distance or effort required to reach that destination into a single value (Kang, 2017; Sevtsuk, 2014). *Betweenness Centrality* is a measure of connectivity between many other locations (Crucitti et al., 2006). When weighted, betweenness is a good indicator of potential traffic flow that a location can expect. It indicates how many times a location is on the shortest path between all other locations on the network (Zhong et al., 2014). The higher the betweenness the more likely that location is on the shortest path between other locations, meaning that the location is an important location for movement within the network.

Closeness Centrality indicates how near a location is to all other locations along the shortest path. This is an indicator of proximity, highlighting the accessibility of a location (Porta et al., 2011). The location closeness is defined as the inverse of the cumulative distance to reach that location from all other locations, potentially within a given search radius (Rodrigue et al., 2016; Sevtsuk, 2014). A lower closeness value (weighted or unweighted) indicates that a location has a denser and better connected network and a higher value (if weighted) within a given radius (Kang, 2017).

Straightness Centrality indicates efficiency by identifying the directness of a path between a location and all other locations. Straightness effectively measures how close the path between two points is to a straight Euclidean line (Porta et al., 2005). The smaller the value the more direct the path is. Straightness is also an indicator of legibility and visibility (Kang, 2017; Porta et al., 2011).

Taking into account the variety of indices to economic centring, all networks, whether internal or external, become a measurable characteristic, especially valid within high density and laminated conditions of space.

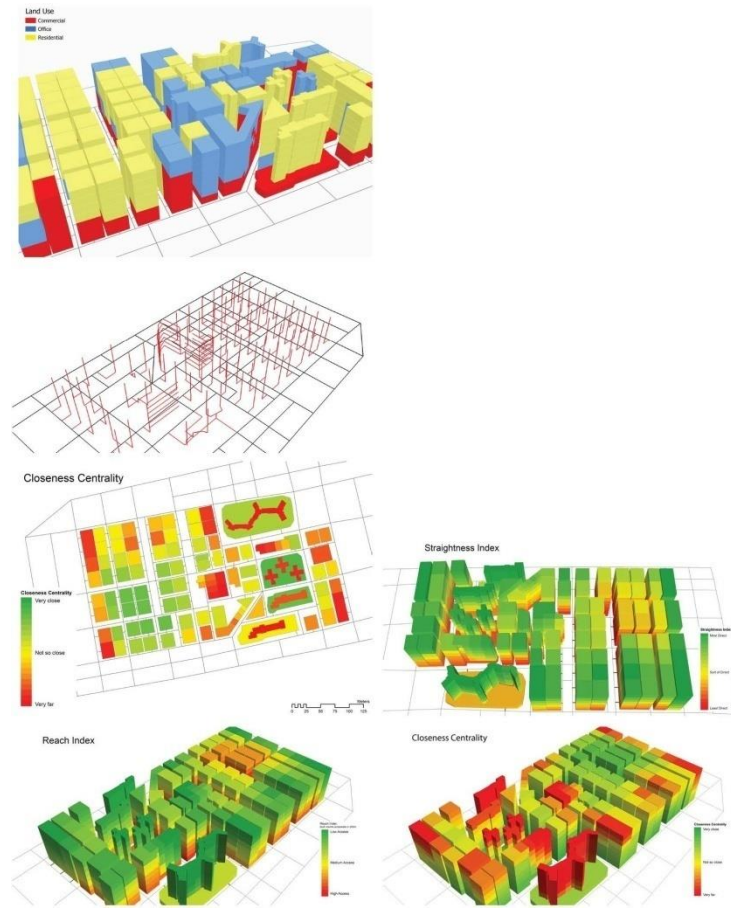


Figure 5. Testing volumetric centrality. Three dimensional land use connected to internal and external circulation networks. Shown here are the effects of *Closeness Centrality* in 2D and 3D, *Straightness Index* and *Reach Indexes*. Source: Authors, 2018

Table

Accessibility and Centrality Measures

Accessibility and Centrality

$$Reach^r[i] = \sum_{j \in G - \{i\}; d[i,j] \leq r} W[j]$$

$$Gravity^r[i] = \sum_{j \in G - \{i\}; d[i,j] \leq r} \frac{W[j]}{\varepsilon^{\beta \cdot d[i,j]}}$$

$$Betweenness^r[i] = \sum_{j \in G - \{i\}; d[i,j] \leq r} \frac{n_{jk}[j]}{n_{jk}} \cdot W[j]$$

$$Closeness^r[i] = \frac{l}{\sum_{j \in G - \{i\}; d[i,j] \leq r} (d[i,j] \cdot W[j])}$$

$$Straightness^r[i] = \sum_{j \in G - \{i\}; d[i,j] \leq r} \frac{\delta[i,j]}{d[i,j]}$$

i: location as the origin; j: destination location; G: network; r: network radius; d(i, j): shortest network distance between locations i and j; $\delta(i, j)$: Euclidian distance between locations i and j; $n_{jk}(i)$: number of routes that pass through location i between j and k in radius r; from location I; n_{jk} : number of paths between locations j and k; Beta(β): decay parameter for units; W(j): weight of location j.

Source: Modified from Sevtsuk and Mekonnen (2012) and Kang (2017).

Conclusion

It is to be understood that the proposed steps summarised here remains part of a methodology in progress. The initial objective of testing the reapplication of the Flat City model in to the volumetric city is an achievable goal in advancing spatial analysis. It is yet to be seen whether this application contributes to a better understanding of network and movement characteristics, the internalization of movement network or what results this approach will generate for a movement-economic comparison in multi- level analysis. Moreover, the work marks a first take on directly linking network analysis and economic values to internal as well as external movement networks.

Secondly, in this process, the dependency a single software alone for the calculation remain ineffective. It was found that more than one software alone falls short to address the complexities of interpretation the internalisation of urban networks and their volumetric relationships. The addition of various formula as well as the visual representation of both the spaces and working process was helpful in advancing each step within the overall hypothesis. At its core, we stress that the advances made here remains at the level of network-volume-complexes and the interpretation of clustering. Moving beyond the obvious spatial comparison, the intentions at a later date would be to challenge other influences that volumetric-economic centring has on social communing and moreover, social mobility.

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